Toward an evaluation of the Alentejo’s olive grove systems sustainability: a proposal by reflecting on life cycle analysis and agrarian metabolism approaches

**Introduction**

Sustainable management of agri-food systems is directly linked to the rational use of available natural resources and existing social and economic pressures.

Sustainability assessment regarding the economic, social and environmental pillars can support decision-making processes, playing a role in planning and project processes’ strategies and operational levels, including policies, plans, programs, projects and activities or operations that address sustainable development goals and indicators (Ramos, 2019). In addition, understanding everything that surrounds this sustainability makes us have an understanding of the environmental, economic and social impacts of these activities, contributing to the management of natural and human systems.

The application of appropriate sustainability assessment methodologies should be considered for taking measures to make those systems more sustainable, taking into account the operationalization of these methodologies by society (Ramos, 2019). In the case of agricultural and agri-food systems sustainability assessment is complex as it has to simultaneously satisfy economic viability, environmental protection and social equity, with the focus on the long term. Moreover, this complexity also concerns being a problem mainly related to the biological characteristics of agricultural production processes

Within the methodologies for assessing, measuring and monitoring impacts there are a set of tools linked to the life cycle methodology. According to De Luca et al., (2015a) life cycle methodologies are recognized as powerful tools that allow to assess the economic performance and estimate the social and environmental impacts of a product or service, also in contexts of agri-food production processes. They are useful tools to characterize and quantify various typologies of impact generated by all stages of a production process. In the evaluation of complex socio-environmental systems, such as agricultural and agri-food ones, uncertainty often arises and the quality of decision processes can be a major concern.

Olive groves are an important crop for the Mediterranean region and the Alentejo region of Portugal. The Alentejo region, despite its dry Mediterranean climate and extensive and multi-functional farming systems, has been experiencing a rapid process of agricultural intensification. This intensification has been fostered by local, national, European and global factors and processes, in close alignment with the dynamics of urban-financial capitalism (Silveira et al., 2018). This intensification and its production practices alter environmental impacts and raise the question of the sustainability of these agricultural systems (Beaufoy, 2001; Romero-Gamez et al, 2017).

The general objective of this paper is to discuss about the use of Life Cycle Management (LCM) tools to analyze the sustainability of olive groves in the Alentejo region of Portugal. Specifically, following the methodological approach proposed in the international project *Sustainolive* (2021) referred in De Luca et al. (2021a, 2021b), life cycle-based methodologies, namely Life Cycle Assessment (LCA), Life Cycle Costing (LCC), social Life Cycle Assessment (sLCA) and Social Agrarian Metabolism (SAM) will be described to argue about their potentiality to effectively measure environmental, economic, and social performances of sustainable management systems in olive growing.

**Context**

The European Union is the leading world producer, consumer and exporter of olive oil, accounting for 68.4% of olive oil produced, 54.2% of olive oil consumed and 66.9% of exports (GPP, 2020). Olive farming is an important cultural and traditional system in the Mediterranean region that has considerable environmental impacts (Camarsa et al, 2010; Mohamad, et al., 2014). Olive grove areas represent 7.7 million hectares in the Mediterranean basin with important environmental, social and economic contributions. It occupies 95% of the total world cultivated area of 10.8 Mha, producing 97.8% of total world olive oil production. European Union (EU) countries produced an average of 2 161 000 tonnes per year (2006-2012) of olive oil (IOC, 2012; FAOSTAT, 2017, Sustainolive, 2021). In Portugal, olive grove production systems have been undergoing major technological changes, such as irrigation, biotechnology, land mobilization and mechanization. Extensive and traditional systems have been progressively replaced by intensive and super-intensive systems generating environmental, social and economic impacts and externalities (Marques, 2017).

Portugal has been self-sufficient in olive oil since 2014 and accounts for 3.4 per cent of world olive oil production (GPP, 2020). The Alentejo olive grove in Portugal represents 40% of the national olive grove area and produces 70% of the national olive oil production (INE, 2017). Out of a total national area of 347 thousand hectares of olive groves, 6% is on olive groves in intensive and super-intensive systems, located mainly in the Alentejo area (GPP, 2020).

**Brief overview of sustainability assessment methods**

For Zhang & Zhu (2020:2) "sustainability can be understood as the achievement of higher levels of well-being distributed more equitably within ecological limits".Sustainable development is proposed based on the “Ends-Means Spectrum” and strong sustainability, which underline that improving well-being is the ultimate goal and ecological consumption is the ultimate means and has biophysical limits (Daly & Farley, 2004; Zhang & Zhu, 2020). The term ‘‘sustainable agriculture’’ means “an integrated system of plant and animal production practices having a site-specific application that will, over the long-term— (A) satisfy human food and fiber needs; (B) enhance environmental quality and the natural resource base upon which the agriculture economy depends; (C) make the most efficient use of nonrenewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls; (D) sustain the economic viability of farm operations; and (E) enhance the quality of life for farmers and society as a whole” (USDA/NIFA, 2002)

Climate change and increasing urbanization pressures add urgency to the challenge of ensuring global food security without compromising the sustainability of social-ecological systems (Garnett et al. 2013). Olive farming has presented changes aiming at increasing productivity and profitability and, according to Caruso et al., (2014) in recent years, the diversity of olive grove management types in the main growing areas has thus increased and, intensification techniques have been widely adopted. This intensification differs from the traditional structure in relation to the performance and technique adopted, such as irrigation, fertilization, mechanical harvesting and pruning. By the rapid adoption and demands of this intensification raises doubts about its future sustainability (Mairech, et al., 2021). Therefore, the adoption of innovative production strategies is necessary to undertake sustainability pathways. The impacts must be assessed so that corrective actions can be taken and public programs and policies that promote them can be shaped. As an example there is the green direct payment or 'greening' which according to European Commission (2021) supports farmers who adopt or maintain agricultural practices that contribute to EU environmental and climate objectives through reward. Under the new Common Agricultural Policy 2023-2027 (CAP 2023-2027) that will start in January 2023, there will be stronger incentives for climate and environmentally friendly farming practices through receipt of green direct payment if they comply with some mandatory practices that benefit the environment (soil and biodiversity in particular).

Improving product sustainability can be achieved by maximizing economic and social values while reducing environmental impact and cost (Hanieh et al., 2020). Therefore, characterizing and quantifying impacts becomes so important to identify the bottlenecks in adopting sustainable management strategies.

Within the life cycle methodologies and that help to assess impacts, there is Life Cycle Thinking (LCT), which concerns the conceptual part and Life Cycle Management (LCM) which is its operational complement. They integrate sustainability priorities throughout the production process, in a systematic way, to improve design, innovation and evaluation activities (De Luca et al., 2017).

For Sonnemann et al. (2015) within LCM there are different tools and concepts that can be used, for example LCA, LCC, sLCA, organizational LCA (OLCA), hotspot analysis, different forms of water footprint and carbon footprint, cost-benefit analysis (CBA), material flow analysis (MFA), substance flow analysis (SFA), input-output analysis (IOA), environmental risk assessment (ERA), among others.

Among the many environmental and economic studies (leaving aside the social aspect) on olive groves, we can highlight for example, Mohamad et al. (2014) compare environmental impacts and economic performances between organic and conventional olive farming systems in the Puglia region (Italy) using LCA to assess environmental impacts, and LCC to assess the economic performance of the studied systems. The study by De Gennaro et al., (2012) performs the environmental and economic assessment of intensive and super-intensive systems by integrating the two methods using a common database.

In order to obtain a complete assessment of the impacts, it can be seen that the joint use of environmental, social and economic analysis tools and methodologies proves to be effective, as it supports decision making and assists the formulation of strategic actions to improve the sustainable management of olive production systems (Remmen et al. 2007). According to Finkbeiner et al. (2010) and UNEP (2011), life cycle sustainability assessment (LCSA) is the combination of LCA, LCC and sLCA to assess the three dimensions of sustainability for products. In this study and several others, such as that of Sala et al. (2017), the importance of complementing LCA with other scientific methods and domains (environmental, social and economic) is highlighted enabling LCA to become a key element for the sustainability of food systems.

De Luca et al., (2021) proposed and are in working progress for the joint application of LCC, LCA, and sLCA as in De Luca et al. (2018), with a further assessment method named Social Agrarian Metabolism (SAM) as in González de Molina et al. (2020), in order to evaluate sustainable technological solutions applied in olive farms compared to typical managerial approaches.

From an environmental perspective, LCA is a technique that identifies “where“ and ”how“ resources are consumed and emissions occur, during the life cycle of a product/service. It ensures that impacts throughout this cycle are addressed in an integrated way, depending on the purpose and scope of the analysis (Cellura et al., 2012; Kyriakopoulos, 2007). It is the compilation and evaluation of the inputs, outputs and potential environmental impacts of a production system throughout its life cycle (ISO, 2006 a, b). A set of indicators, corresponding to different impact categories, are calculated using data available from dedicated databases through specific software for impact characterization.

Aware of the economic importance of olives in several countries, olive oil production is linked to several adverse effects on the environment, such as resource depletion, land degradation, air emissions, and waste generation. These impacts can vary substantially according to the practices and techniques adopted in this sector (Salomone and Ioppolo 2012). As a consequence, tools such as LCA are becoming increasingly important for this type of industry (Salomone et al., 2015). In this sector, especially agricultural production represents the critical phase of LCA, due to the need to model the interactions between biological phenomena and human activities that may increase the uncertainty of the results (Cerutti et al., 2015).

LCC is an economic tool that allows important decisions to be adopted in the design, development and implementation of projects/products (ISO, 2008; Farr, 2011). It performs the economic valuation of resources (i.e. inputs) and environmental impacts (i.e. externalities) and identifies the bottlenecks of adopting a sustainable strategy (Farr, 2011). LCC is dedicated to the elaboration of an account of all costs generated throughout the life cycle (Hunkeler et al., 2008; Iofrida et al., 2018). So LCC does put a price on environmental impacts. If all impacts have a price, they can be added up and the product has a price that representing its total environmental burden (Brouwer, 2020).

Within the umbrella of life cycle-based approaches, social impacts potentially generated from a production process are considered by means the youngest of methodologies, the “so-called” social LCA, that attempts to follow the same procedures and step of LCA, even up to now there has not yet been an unambiguous consensus and a recognized standardization of the method l (De Luca, et al., 2015a; De Luca et al. 2015b; Iofrida et al., 2018a, 2018b). Several approaches have been proposed by sLCA scholars and some of them are described by the “Guidelines for Social Life Cycle Assessment of Products” (UNEP/SETAC, 2012, 2020) .

Social Agrarian Metabolism (SAM) shows itself as a concept that today is perhaps the most powerful theoretical tool to jointly analyze the relationships between natural and social processes (Toledo 2011). The seminal character of the concept of metabolism comes from Karl Marx (1818-1883), when he draws on an environmental perspective as a way to ground the transformation of society since the capitalist logic is not sustainable and depletes the forces of labour and the land (Boron et al, 2007). The concept remained dormant for decades, until the late sixties of the last century, when economists who had worked in the field of social metabolism for decades, rediscovered the concept of social metabolism, even without knowing its origin (Toledo, 2013). It can be understood as the application of the metabolic approach to the field of agriculture, that is, it is the study of biophysical flows that maintain the generation of biomass and environmental services, considering that nature influences particular aspects of social systems in the same way that different social systems influence the environment (González de Molina; Toledo, 2011).

It is from the exchanges between society and nature that society feeds all the materials, energies and environmental services that humans and their artefacts need to maintain and reproduce (Toledo, 2008). It refers to the appropriation of biomass by members of society through the management of the agroecosystems present on the land (Guzmán Casado and González de Molina 2017).

The strong interaction between humans and nature, in the context of agriculture, is undeniable and it is also inevitable to think that, because of this strong connection, some environmental problems may occur (Souza, 2013). In the case of olive intensification, the negative environmental effects, already cited, could be reduced considerably using appropriate farming practices; and, with appropriate support, traditional low-input plantations could continue to maintain important natural and social values (Pienkowski & M., Beaufoy, 2002). Therefore, whether analyzing economic, environmental and/or social sustainability, the important thing is that this process is carried out using the right tools that are most adapted to the context studied, producing clear results that have practical applicability.

**Methodology**

The choice to highlight in this paper some evaluation tools follows the combined methodology proposed by De Luca et al., (2021a, 2021b) and Sustainolive (2021), through LCT, with selected methods of LCC, LCA, social SLCA, and SAM, that will results, once the implementation and processing have been conducted, in the analysis of costs, economic performance, environmental impacts and social sustainability.

The combination of these approaches, vis-à-vis the ones initially mentioned (environmental and economic, without considering the social aspect), prove to be original, to our knowledge, never have life cycle perspectives been equated with SAM which, according to Gonzales de Molina et al. (2020), measures the mutual dependencies incurred during the interaction between nature and society by measuring the flow of integrated and reproductive biophysical funds.

LCC as economic tool is susceptible to be applied to olive groves and olive oil production systems to support producers, to understand the profitability levels of production systems and to inform the long-term management strategy of policy-makers.

LCC looks at the total of direct and indirect, recurring, non-recurring, and other related or estimated costs over the lifetime (ISO, 2008; Farr, 2011). That is, all costs incurred in the life cycle of the olive grove (planting costs, operating costs and disposal costs), as well as the revenues obtained by multiplying the average olive production by its market price and adding additional revenues (CAP payments, disposal revenues, etc.) (Stillitano et al., 2016; Stillitano et al., 2019; Guarino et al., 2019).

Tools such as LCA are becoming increasingly important for the olive industry, both at the agricultural stage and in olive oil production (Salamone et al., 2015; Romero-Gamez et al., 2017). Intensive olive growing is a major cause of one of the most serious environmental problems affecting the EU, especially agricultural production (Beaufoy, 2001; Marques, 2017).

From a methodological point of view, an appropriate and correct LCA is conducted following four standardized steps (Figure 1): purpose and scope definition; inventory analysis; impact assessment; and interpretation (ISO 2016 a, b). Being structured in these phases, regardless of the type of LCA, the process of the assessment remains the same (UNEP/SETAC Life Cycle Initiative, 2012).

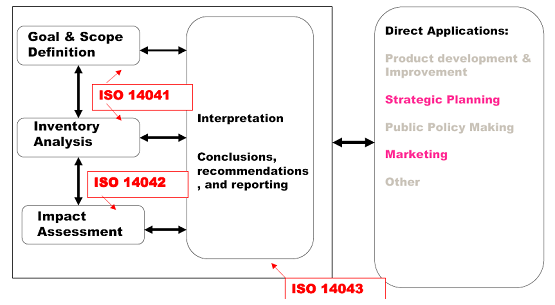
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Figure 1 – Life cycle assessment process   
Source: https://grimstad.uia.no/puls/climatechange2/nns05/13nns05a.htm

The objective is defined according to the main reason for conducting the study, its scope and the target audience for which the results are intended. On the other hand, the definition of the scope considers methodological aspects of the study, such as the establishment of parameters such as function, functional unit and product reference flow, the setting of boundaries, criteria for the allocation of environmental loads, as well as the impact categories to be used in the corresponding naming stage (Guinée, 2006; Curran, 2016). In the second stage, the Life Cycle Inventory (LCI), there is data collection (primary or secondary), which according to ISO (2006a), as data is collected and knowledge about the system is expanded, new data requirements or limitations may be identified, requiring a change in data collection procedures so that the study objectives can still be met. There is also the quantification of all variables that relate to the life cycle of a product, process or activity, namely raw materials, energy, transportation, air emissions, effluents, solid waste, among others (Seo and Kulay, 2006; Guinée, 2006; Curran, 2016). Through the association between inventory data, impact categories and category indicators, Life Cycle Impact Assessment (LCIA) aims to understand these impacts (ISO, 2006a). It represents a process of understanding and assessing environmental impacts, which is based on the results obtained in the inventory analysis, taking into account the effects that may be caused to the environment and human health. Through the analysis of the results of the inventory and impact assessment phases, the interpretation is performed, which may result in conclusions and recommendations to assist the decision-making process (Seo and Kulay, 2006; Guinée, 2006; Curran, 2016).

Analyzing the sLCA, which assesses social impacts, means understanding the consequences of a life cycle operation on people, actions and social phenomena. For Macombe et al. (2013) this tool addresses issues of human rights, health and safety, and governance, among others, while taking into account the utility of the product.

From another perspective of analysis, SAM analyzes the biophysical flows that maintain the generation of biomass and environmental services, considering that nature influences particular aspects of social systems in the same way that different social systems influence the environment. Using the SAM, information on biophysical functioning is obtained producing synthetic indicators of sustainability. Therefore, it refers to the exchanges of energy, materials and information established by the agrarian sector of society with its socio-ecological environment (Toledo, 2008).

**Expected Results**

The integrated analysis of LCC, LCA, SLCA results in the Life Cycle Sustainability Assessment (LCSA) for budgeting and economic performance assessment, estimating simultaneously the social (together with SAM) and environmental impacts of olive production systems.

The application of LCC allows achieving two main objectives: to adapt cost estimation approaches to relate environmental costs to specific processes and products, and to facilitate the identification of best practices to prevent pollution and reduce waste (Stillitano et al., 2016).

LCA has become a key tool to compare environmental impacts between alternative systems and different scenarios in the agricultural sector to suggest the most sustainable production technique (e.g. conventional versus organic) or the most sustainable product (e.g. comparison between different cultivars) or other alternatives (Iofrida et al., 2018). It can then be used as a decision tool to support the choices of producers of the surveyed product, to improve the ecological profile of the related production system and to inform the long-term management strategy of policymakers.

In agriculture, as in other sectors, LCA practitioners have, over the last decade, been dedicated to linking environmental assessment with economic and social aspects. It, therefore, becomes important to understand sLCA. This tool that assesses social impacts, has its roots in the cultural and scientific heritage of the social sciences and especially the management sciences. It can help organizations to make decisions on how to organize production processes according to the social impacts that they can potentially generate (negative to avoid and positive to encourage) (Iofrida et al., 2018).

From another perspective of analysis, SAM, in dealing with socio-metabolic transformations, presents, on the one hand, a critical grounding on the industrial aspects that influence agricultural activities in the process of modernization of the countryside. On the other hand, it has placed great emphasis on the importance of studies on peasant knowledge, which is fundamental for understanding the more sustainable management of agroecosystems (González de Molina, 2011). The SAM approach is committed to offering horizons of analysis that guide us towards the achievement of increasingly sustainable societies (Lopez, 2014).

The applicability of these life cycle techniques in conjunction with SAM, for the Alentejo region becomes adequate, as it is the main olive oil producing region of Portugal and, therefore, needs to continue to develop and maintain itself through a sustainable management. Knowing the results and analysis of these techniques that can point where it is possible to mitigate the existing impacts, producers can adapt to the requirements of CAP and consequently receive incentives for sustainable agricultural practices. By using these techniques together it is possible to have an objective assessment of the possible consequences of the olive life cycle operation, such as impacts on workers' health, biodiversity and regional economy, environmental costs, among others.

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